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Diode pumping and wide IR tunability of $ZnSe:Cr^{2+}$ lasers

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A $ZnSe:Cr^{2+}$ laser operated diode-side-pumped with a 1.65 μm InGaAsP/InP array. With a diffraction grating and $MgF_2:Co^{2+}$ laser pumping, it covered the 2150 - 2800 nm range.

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Recently, the divalent-transition-metal-doped II - VI material class has been proposed as a source of new tunable mid-IR lasers. Spectroscopic evaluation[1] exposed Cr^{2+} as a prime laser candidate, with a high luminescence quantum yield and predicted absence of ESA. ZnSe and ZnS hosts gave laser action in a confocal cavity end-pumped with a focused, pulsed ~1900 nm $MgF_2:Co^{2+}$ laser.[2, 3] Untuned operation centered around 2350 nm; an intracavity birefringent filter gave 2280 - 2530 nm tunability. Development possibilities for this material class include construction of a diode-pumped laser system and extension of its tuning range.

Spectroscopic parameters (see Table I) impact the laser design. $ZnSe:Cr^{2+}$ is called "the Ti-sapphire of the mid-IR" because of its similar electronic transition symmetry, short energy-storage lifetime (~9 μsec,) and broad emission linewidth. However, it has a drastically smaller saturation intensity $\mathbf{I_{sat} = h\nu/\sigma\tau}$ ~14 kW/cm^2. Generally, efficient laser operation mandates a pump intensity on the order of I_{sat}, although side-pumped configurations ease this requirement. The low I_{sat} value enables efficient diode-pumped laser performance with "radiance conditioned" 1.8 μm pump diode arrays that deliver modest intensities of a few kW/cm^2.

Our diode-pumped laser design (Figure 1) resembles a previously-reported diode-pumped $Nd:YVO_4$ laser.[4] The output of four microlensed 1.65 μm InGaAsP/InP diode bars is combined in a cylindrical lens and focused to a stripe on a ZnSe:Cr slab. The single bounce at the "TIR interface" allows the resonated beam to sample the high-gain pump face region, yet enter and exit the crystal without aperture losses. Operated at a low duty cycle, the diode array gave a maximum power of 75 W. Slope-efficiency data for the integrated laser using a series of flat output couplers showed the threshold energy increasing substantially for output coupling values above 10%, reflecting a crystal passive loss estimated at $\alpha_{\mathbf{loss}} \sim 15\%/\mathrm{cm}$. The maximum peak output power of 0.34W was achieved with the 90% -reflecting output coupler. The peak absorption coefficient (at 1.8 μm) was $\alpha_{\mathbf{max}} \sim 4.4\ \mathrm{cm}^{-1}$, and we estimate a ~6% "mode fill" (fraction of pump light absorbed in the resonated-mode volume.) A "figure of merit" **FOM** $\equiv \alpha_{\mathbf{max}}/\alpha_{\mathbf{loss}} \sim 27$ characterizes crystal quality; our crystal-growth efforts are aimed at raising the doping level and pump absorption without increasing the passive loss.

For tuning experiments, a 420 line/mm diffraction grating replaced a high-reflector, and a pump beam from a MgF_2:Co^{2+} laser took the place of the diode array. According to Figure 2, the long-wavelength lasing limit was ~2670 nm, but OH-absorption-free substrates allowed output up to 2800 nm. The ~2150 nm short-wavelength cutoff is probably due to self-absorption from the long-wavelength tail of the pump band.

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References

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3. R. H. Page, L. D. DeLoach, K. I. Schaffers, F. D. Patel, R. J. Beach, S. A. Payne, and W. F. Krupke, "Recent developments in Cr^{2+} - doped II - VI compound lasers," OSA Trends in Optics and Photonics on Advanced Solid State Lasers, Stephen A. Payne and Clifford R. Pollock, eds. (Optical Society of America, Washington, DC 1996), Vol 1, pp. 130 - 136.

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Figure Captions

Table I. Spectroscopic properties of Ti^{3+} in Al_2O_3 and Cr^{2+} in II-VI hosts; the low $\mathbf{I_{sat}}$ value for the latter enables diode-pumped laser operation.

Fig. 1. Diode-side-pumped laser design, which facilitates integration of a ZnSe:Cr slab and a multiple-bar diode array.

Fig. 2. Output-coupler transmittance and tuning range demonstrated with MgF_2:Co^{2+} laser pumping of ZnSe:Cr, tuned with a diffraction grating. The OH absorption in the glass substrate material blocked the laser's output from ~2650 - 2800 nm.

		$Ti^{3+}:A\ell_2O_3$	$ZnSe:Cr^{2+}$
Transition		$^2E \rightarrow {}^2T_2$	$^5E \rightarrow {}^5T_2$
Upper-level lifetime	τ_{em} (μsec)	3	9
Peak fluorescence wavelength	λ_{max} (nm)	800	2300
Fluorescence linewidth (RT)	$\Delta\upsilon$ (cm^{-1})	4300	1700
	$\Delta\lambda$ (nm)	300	1000
Relative bandwidth	$\Delta\lambda/\lambda_{max}$	0.38	0.43
Peak pump cross- section	σ_{abs} (10^{-20} cm^2)	6.5	87
Pump saturation intensity	I_{sat} (kW/cm^2)	2000	14

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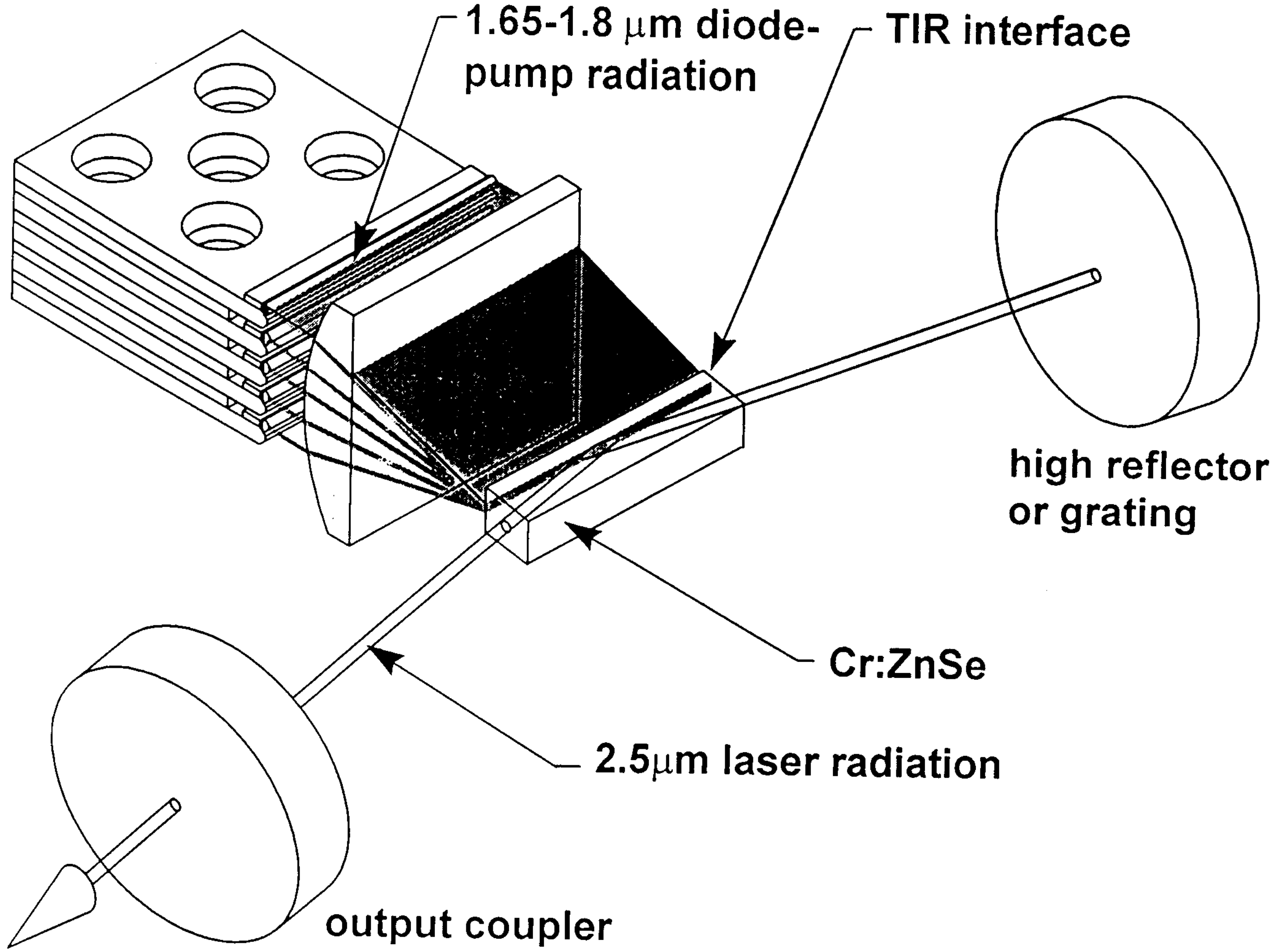
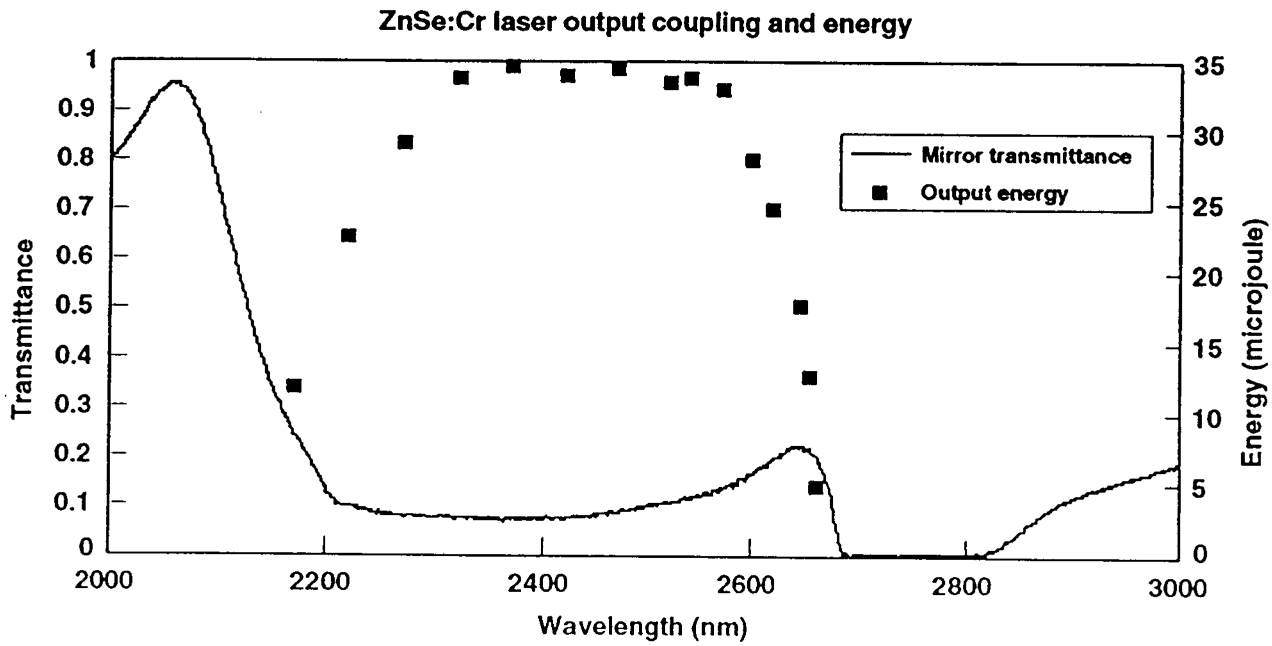

1.65-1.8 μm diode-pump radiation
TIR interface
high reflector or grating
Cr:ZnSe
2.5μm laser radiation
output coupler



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"Diode pumping and wide IR tunability ..."